Overview of ASCAC & the MDOB

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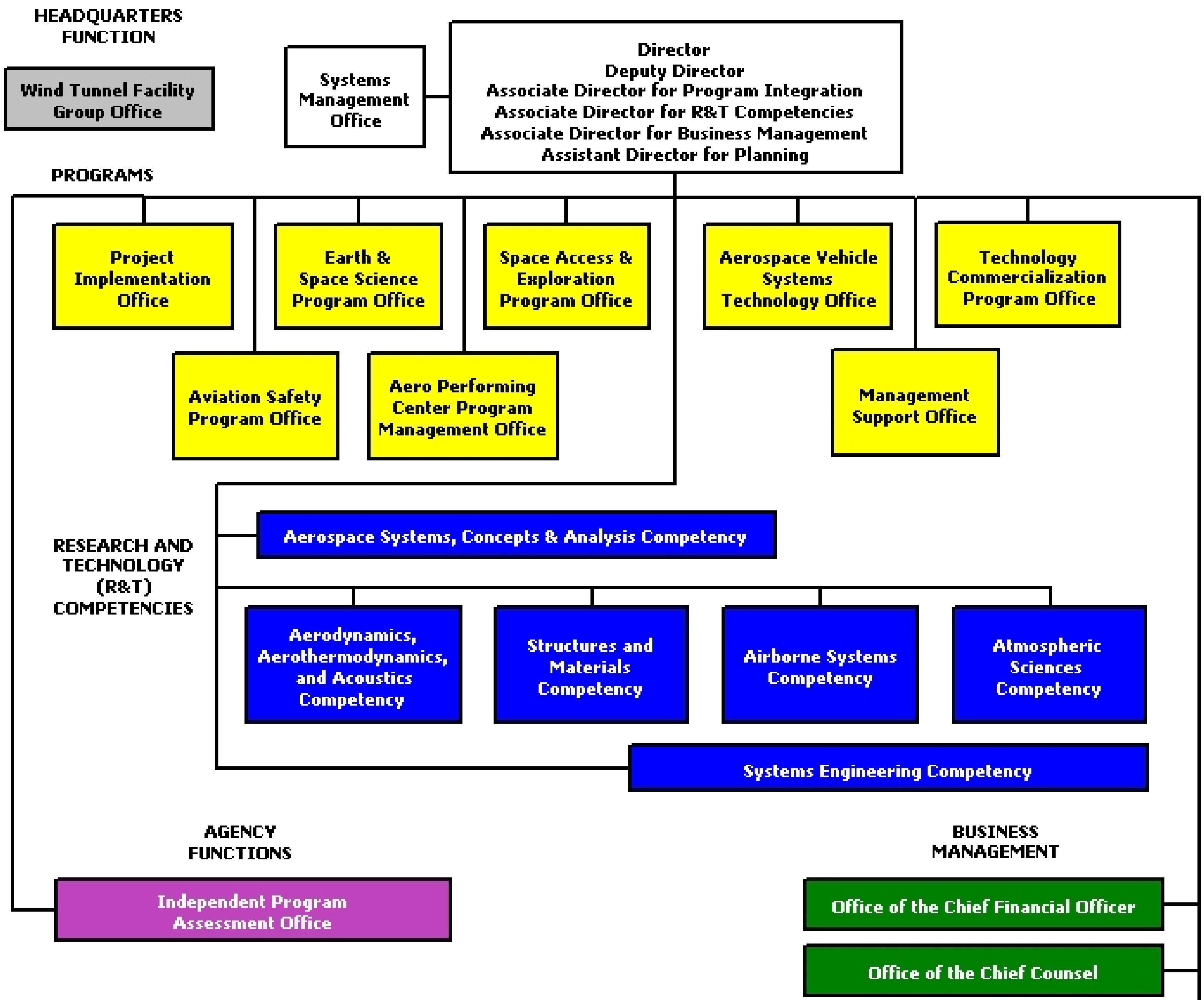
NASA Langley Research Center (LaRC)

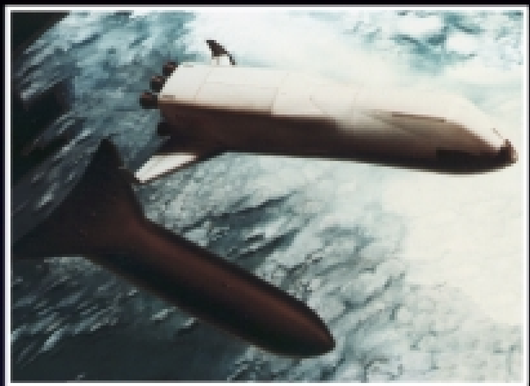
Outline

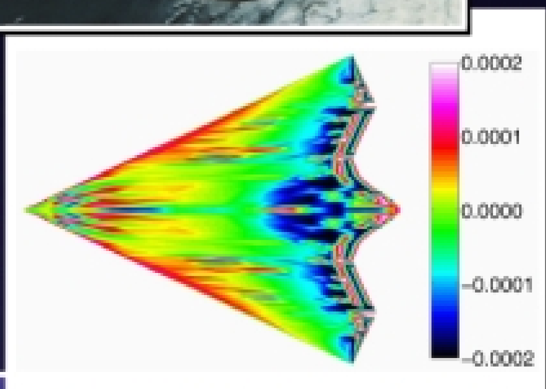
- **ASCAC and MDOB in the current LaRC Organization**
- **MDOB Background**
- **External & Internal Input on MDO Needs**
- **Sponsoring NASA Programs**

Current LaRC Organization



Aerospace Systems, Concepts and Analysis Competency

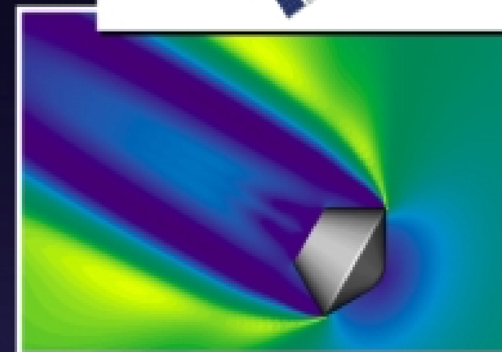


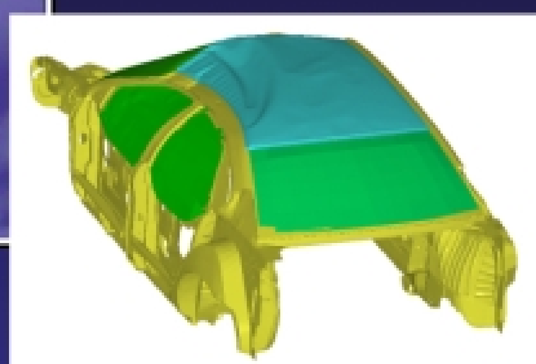


From the Runway to the Planets...

Improving Quality of Life and Enabling Exploration

- ***Technology Payoff***
- ***Lower Cost***
- ***Safety***
- ***Environment***
- ***Performance***





ASCAC Areas of Expertise

- **Aerospace Mission Analysis**
  - **for synthesis of advanced aerospace missions to address requirements resulting from science, commercial, and exploration requirements.**
- **Aerospace Systems Analysis & Concept Development**
  - **to define aerospace vehicles and spacecraft concepts from a systems perspective to satisfy prescribed mission architectures and identify enabling technologies for performance, cost and safety**
- ***Advanced Analysis and Design Method Development/Application***
  - ***to enable the mission and system analysis and technology trades for advanced aerospace system concepts***
- **Technology Impact Analysis**
  - **to investigate and analyze the impact of key critical technologies on the feasibility and operation of aerospace vehicles**

Aerospace Systems, Concepts and Analysis Competency

Space Transportation & Planetary Analysis

Vehicle Analysis Branch

Advanced Civil Airplane & Transportation Systems Analysis

Systems Analysis Branch

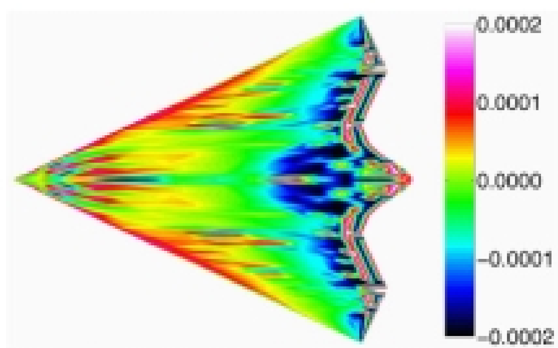
Survivable, Advanced, Military Vehicles

Advanced Aircraft Branch

Space Mission Analyses

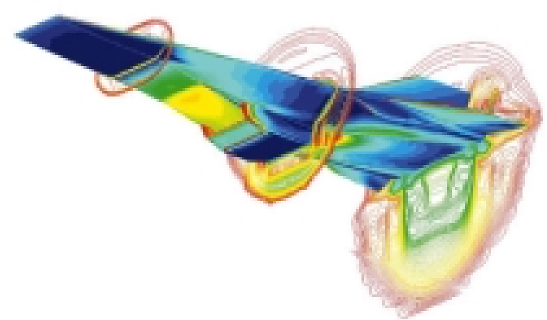
Spacecraft & Sensors Branch

Multidisciplinary Design Optimization



MDO Branch

Computational Aerosciences



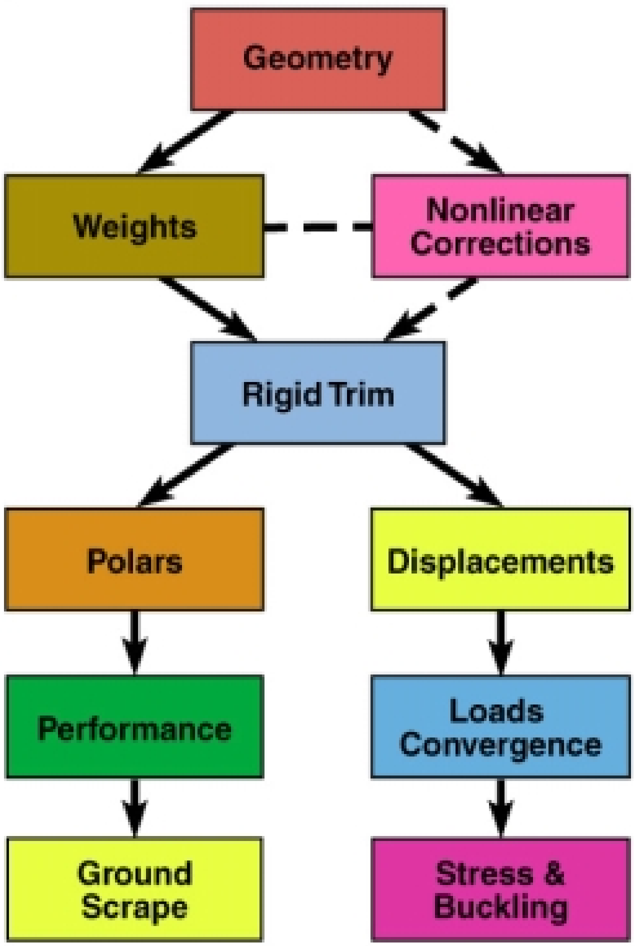
CAS Team

Multidisciplinary Design Optimization

Charter: develop MDO methods to increase design confidence and to cut development time

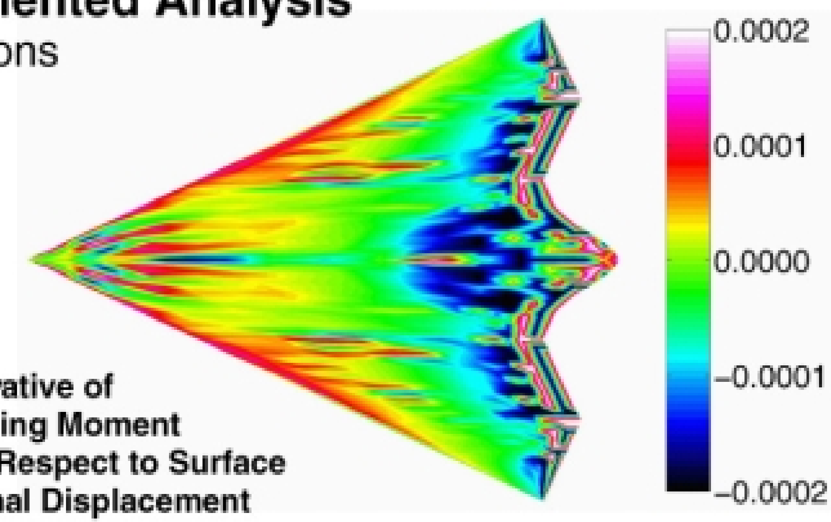
Multidisciplinary Optimization

Integration Methods
Optimization Methods



Design-Oriented Analysis

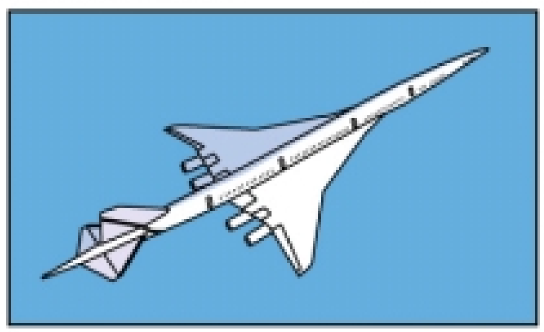
Approximations
Sensitivity



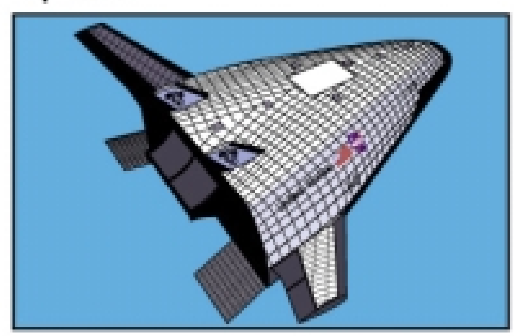
$\partial C_M/\partial z$: Derivative of Pitching Moment with Respect to Surface Normal Displacement

High-Fidelity Applications

Aeronautics

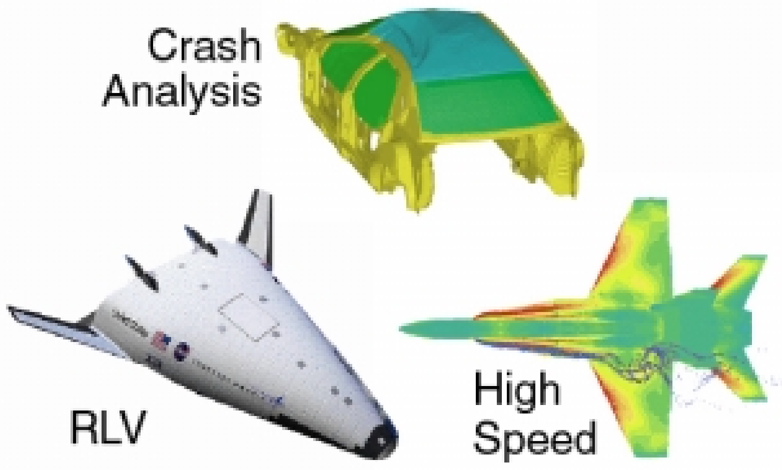


Space

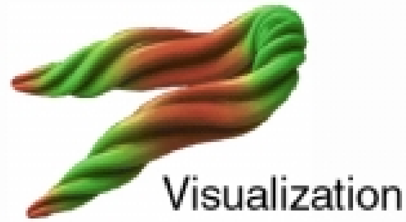


Computational Aerosciences

Complex MDO Applications



Basic Research/System Software

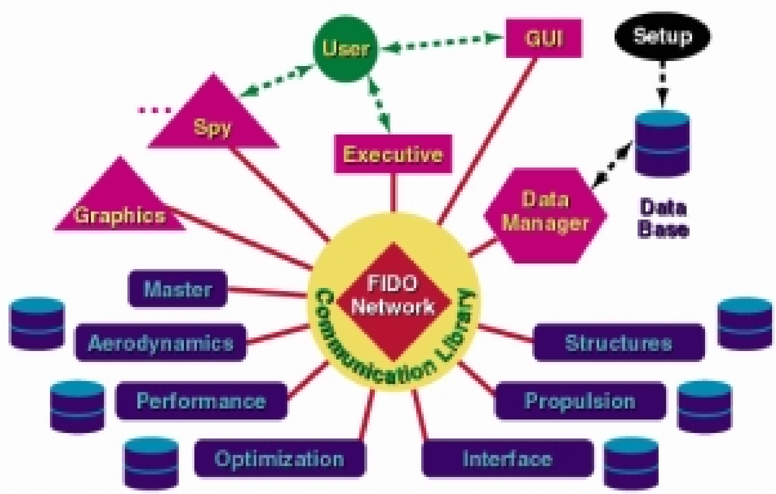


Learning Technologies

Educational technology to develop future scientists and engineers skilled in high performance computing

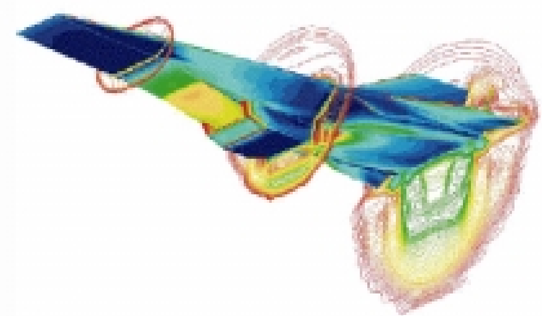
Computational Frameworks

FIDO Execution System



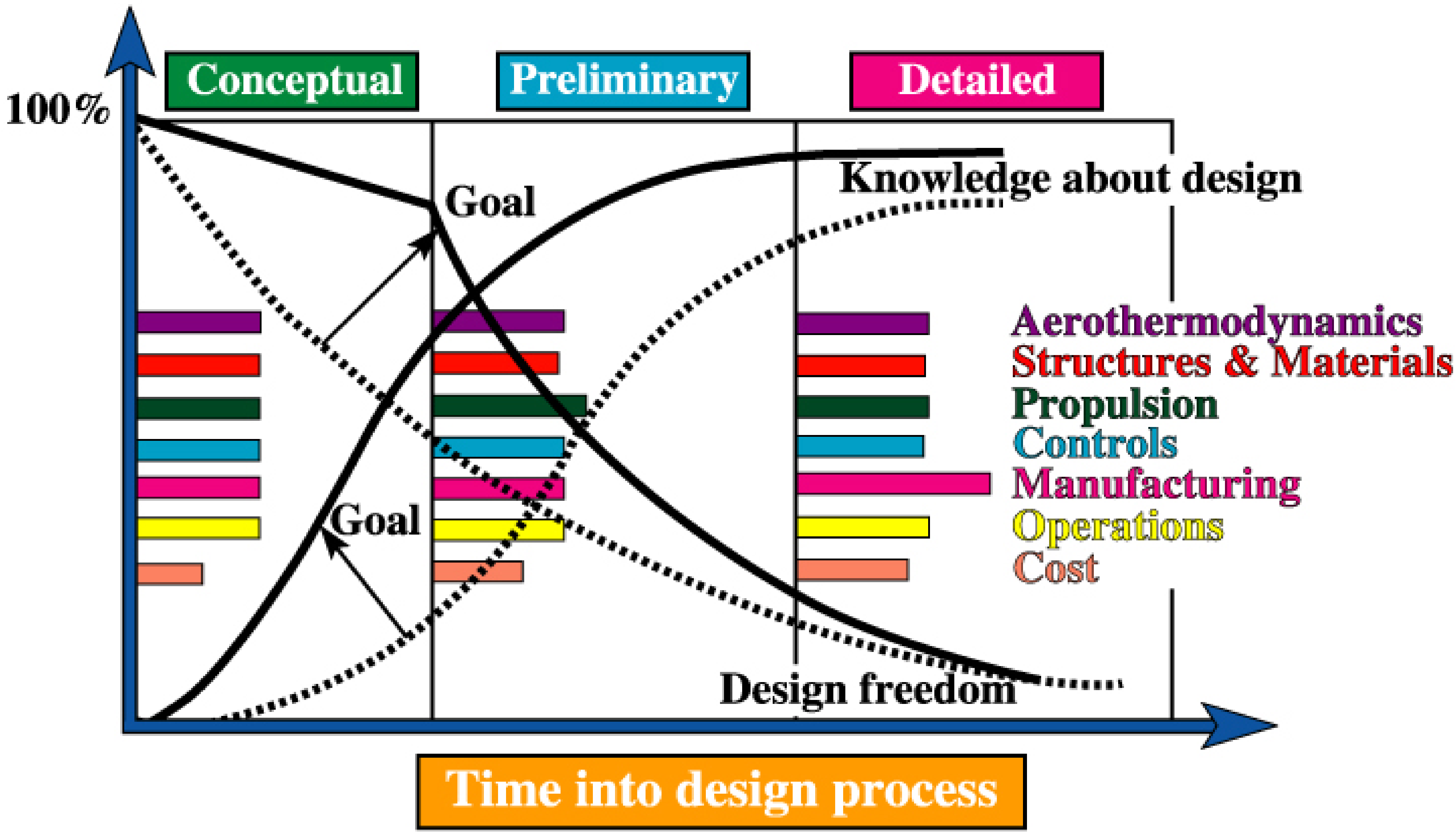
Advanced Methods

"Compute as fast as engineers can think."



Aerospace Design Vision

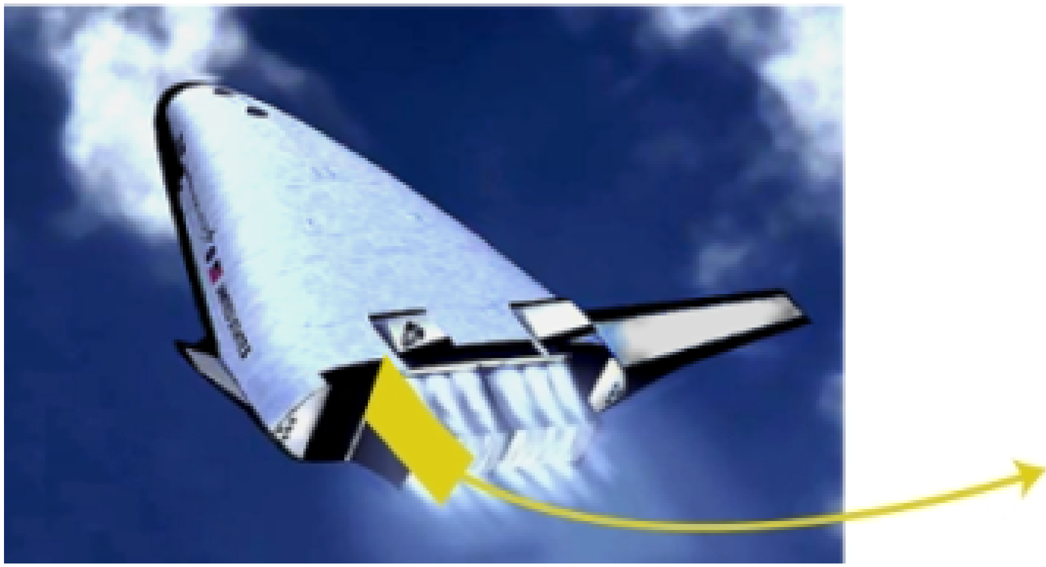
Improved Distribution of Knowledge and Efforts



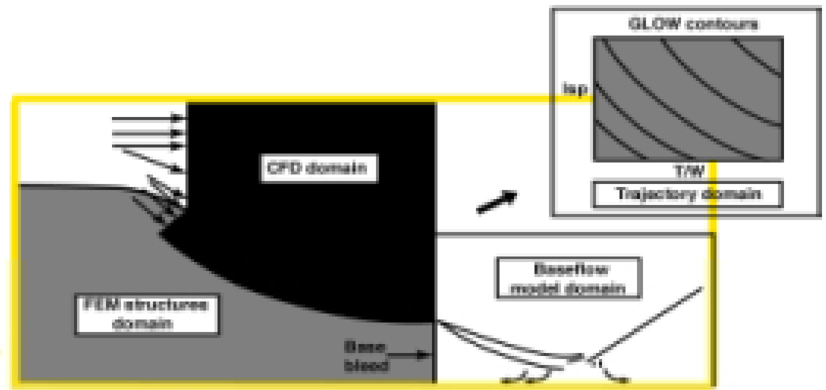
MDO Definition

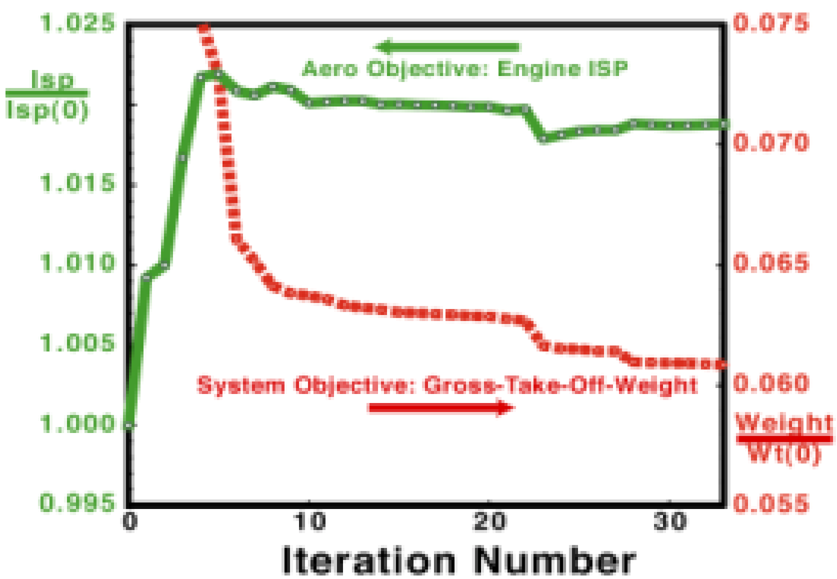
Multidisciplinary Design Optimization (MDO) is a methodology for the design of complex engineering systems and subsystems that coherently exploits the synergism of mutually interacting phenomena

MDO Applied to an Aerospike Nozzle

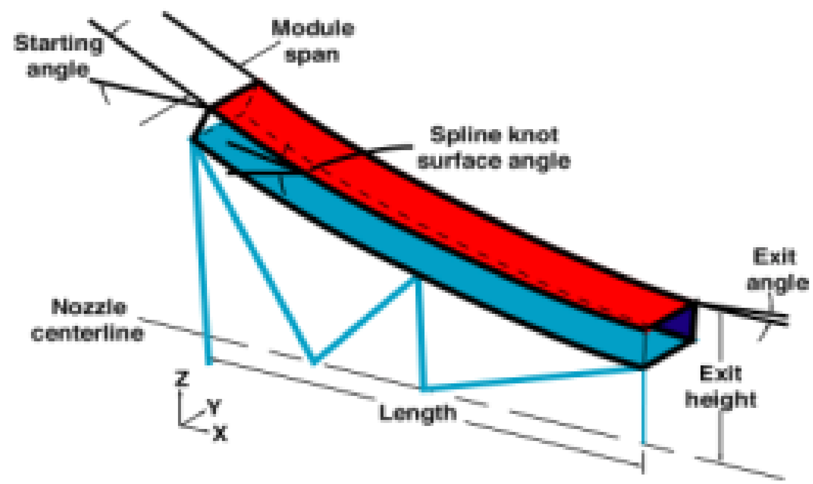


Nozzle Modeled by a 2-D Section



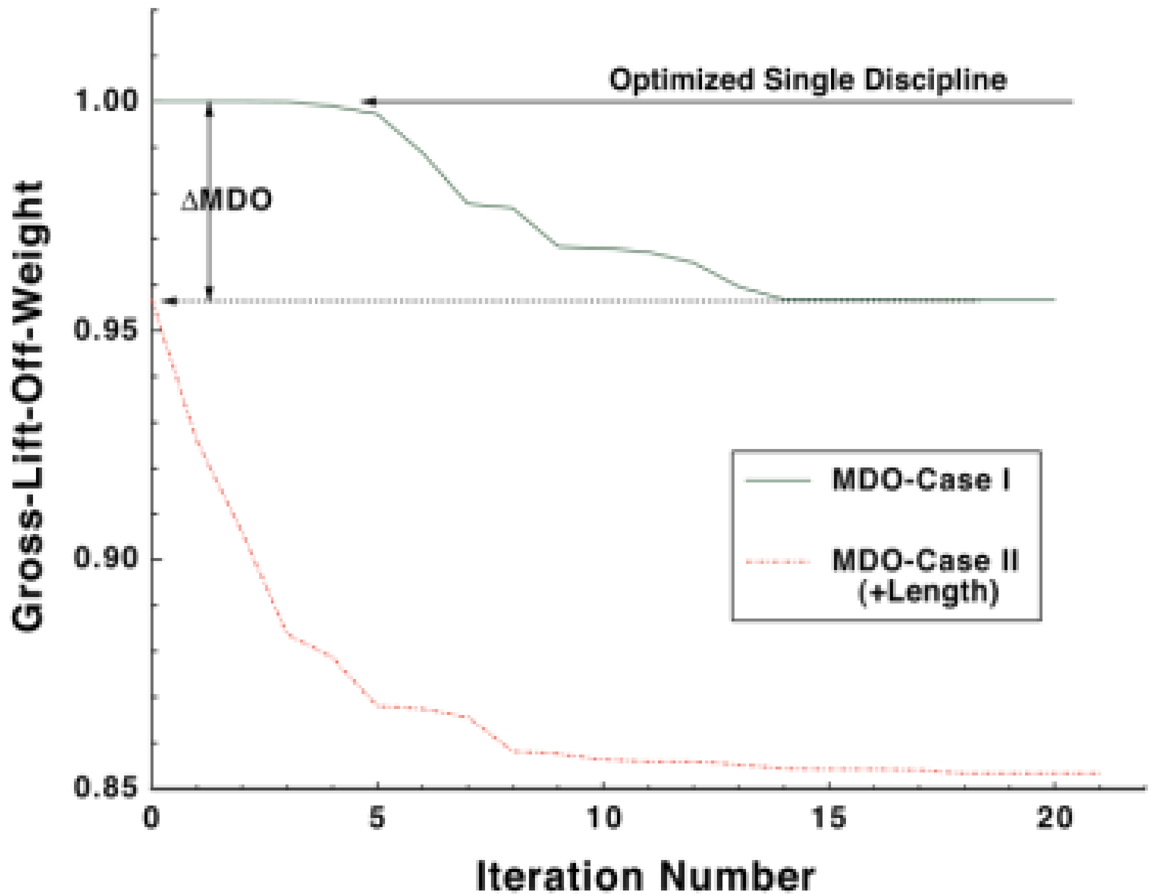


Nozzle Geometry Design Variables



MDO Impact on Aerospike Nozzle Model Problem

- **Sequential Design**
  - optimize the aero shape for maximum Isp
  - then optimize the structure for minimum GLOW
- **MDO Design**
  - optimize the aero & structures together for minimum GLOW
  - produces 4% reduction in GLOW



MDR Conceptual Elements

Analysis and Approximations	Design Problem Formulations and Solutions	Information Processing and Management	Organization and Culture
Cost-fidelity trade-off	Design problem formulation	Software engineering	MD Training
Approximations	Problem de- /re- composition	Data and software standards	MD process insertion
High-fidelity results inclusion	Optimization algorithms	Data visualization, storage, management	MD in integrated product teams
Parametric product data models	Optimization procedures	MD environment	MD in existing organization
SD analysis and sensitivity analysis	SD optimization	Human interface	
MD analysis and sensitivity analysis	MD optimization	MD computing	

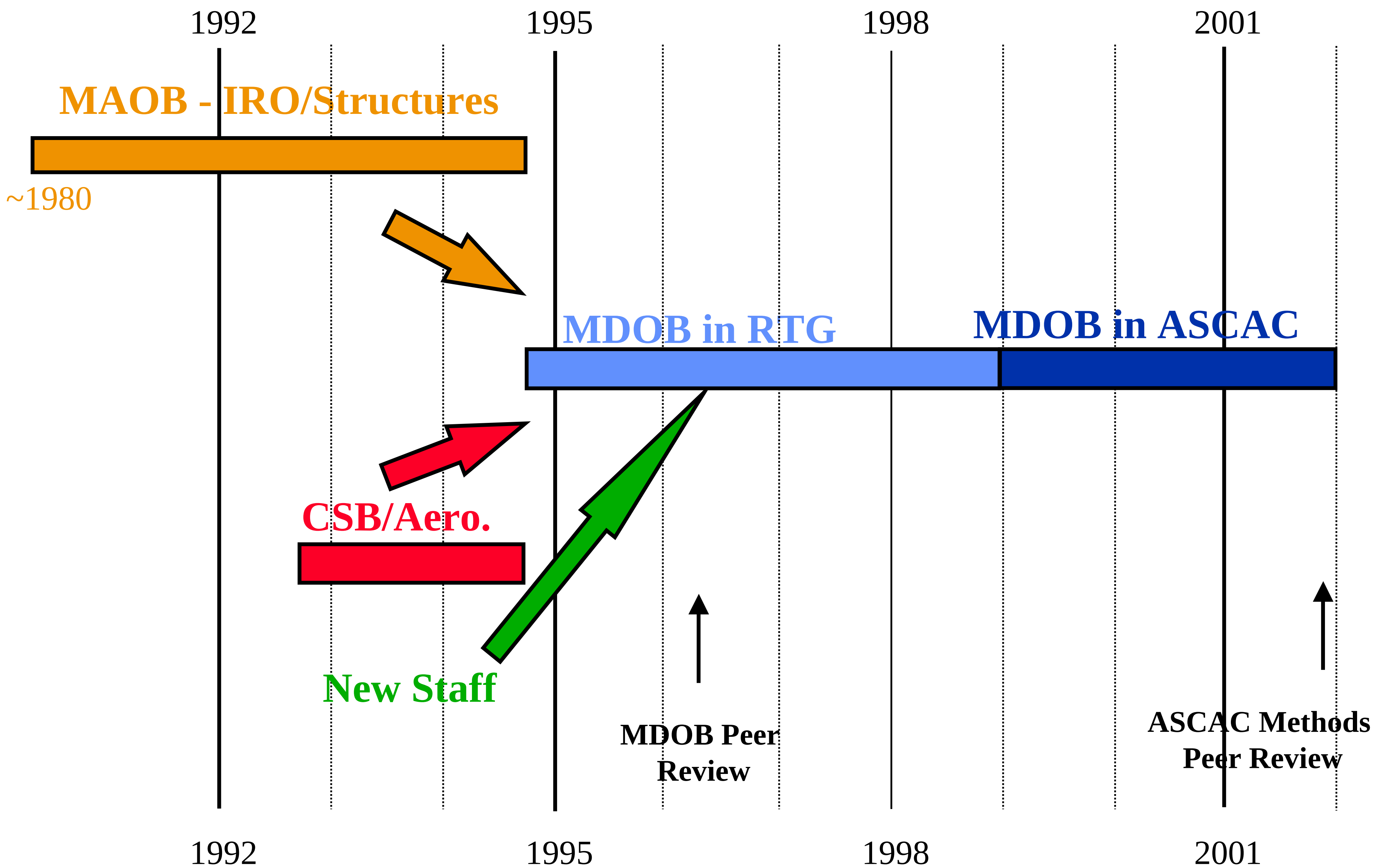
* *Based on Special Session on Industry Needs at 1998 AIAA/MA&O*

LaRC MDO Role

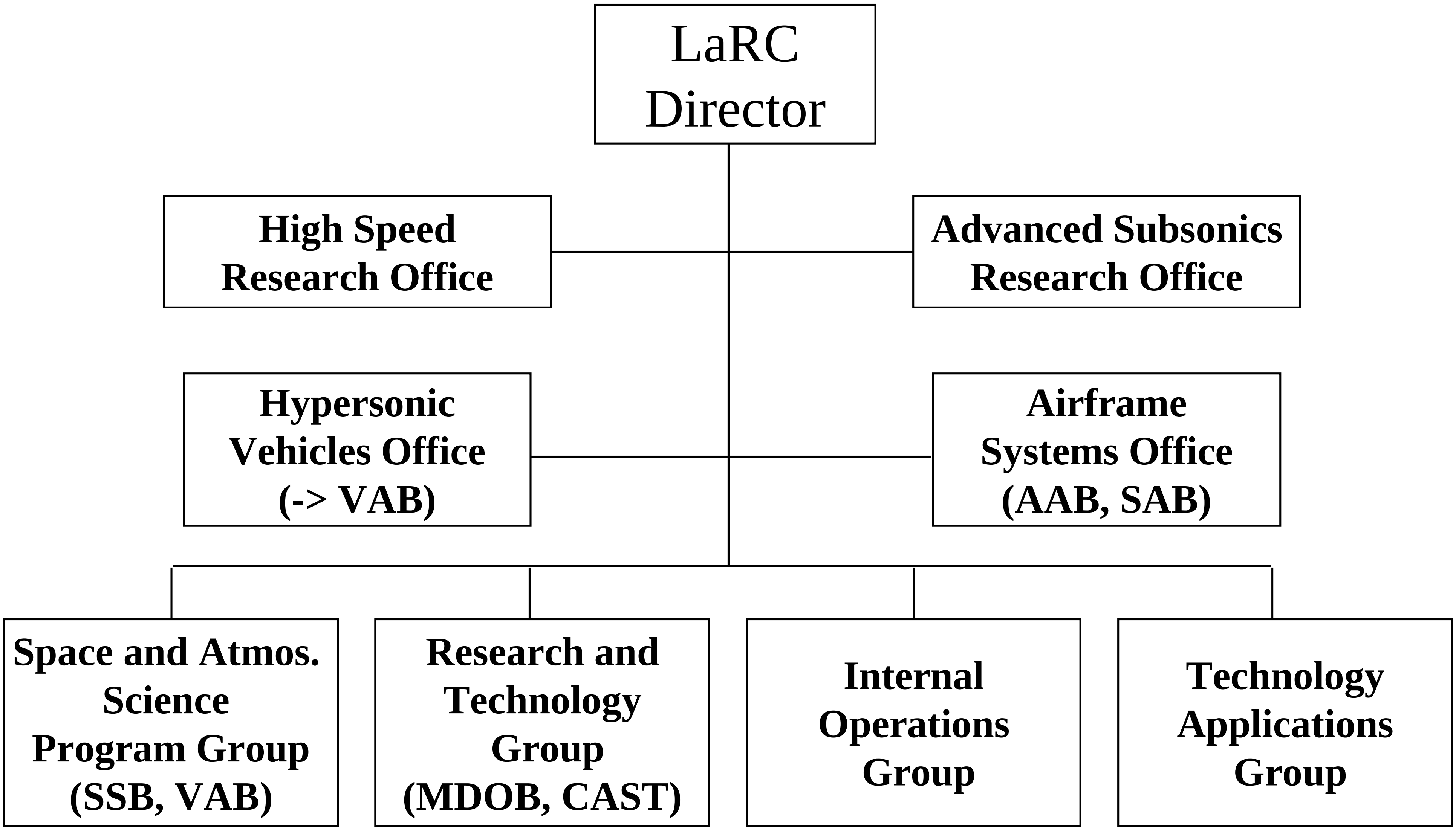
LaRC performs MDO R&D in the technical areas covered by the MDR Conceptual Elements to provide advanced MDO Technology

- **to the U. S. Aerospace Industry [*1995 emphasis*] for applying MDO in the design of aerospace vehicles**
- **to NASA organizations [*2000 emphasis*] performing a Mission/Systems Analysis function for use in**
  - **conducting multidisciplinary systems studies of advanced aeronautical vehicles and the air traffic system including economic and risk assessment analyses (SAB & AAB)**
  - **conducting system analyses & technology assessments to identify & enhance technological advancements for space transportation, spacecraft and instruments concepts (VAB & SSB)**

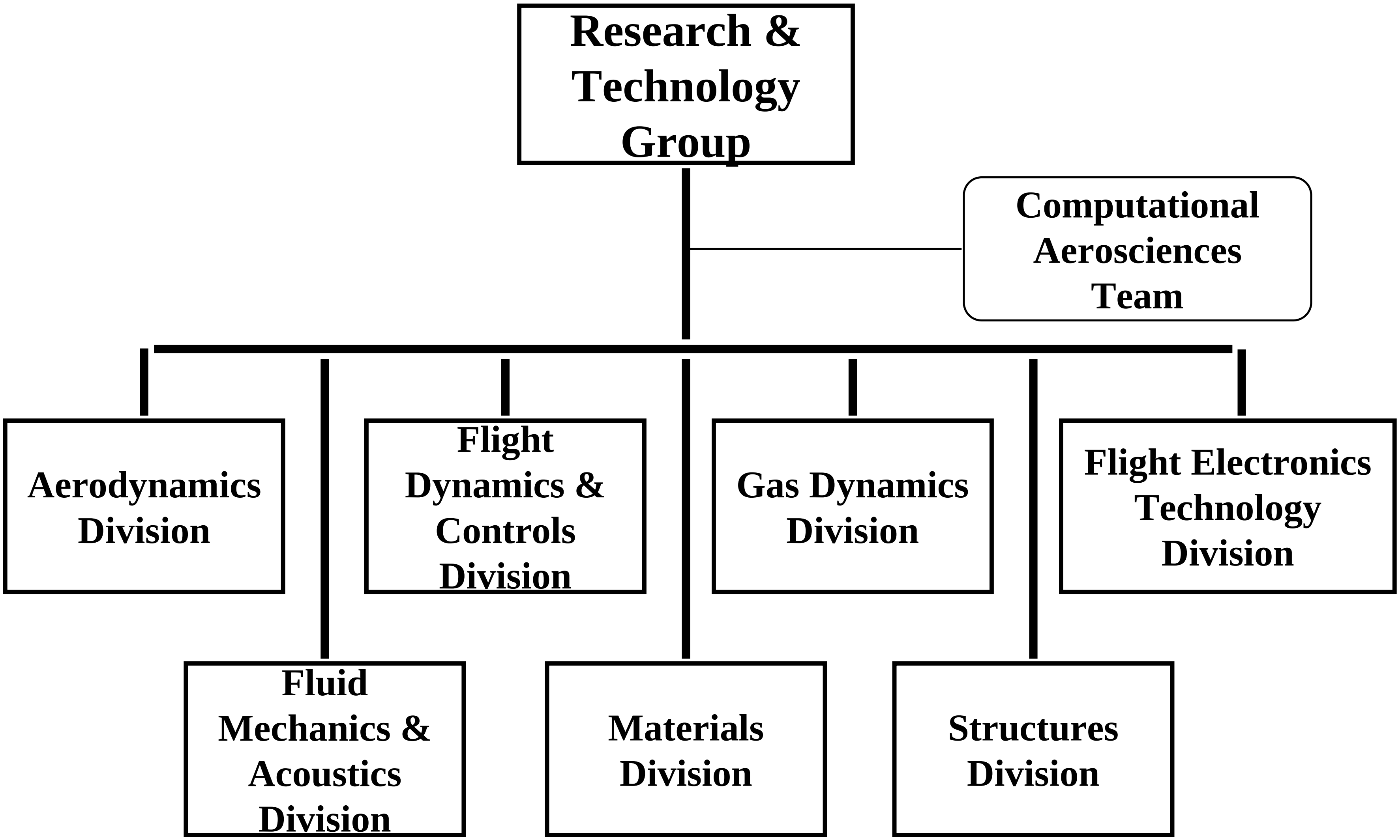
MDO at Langley



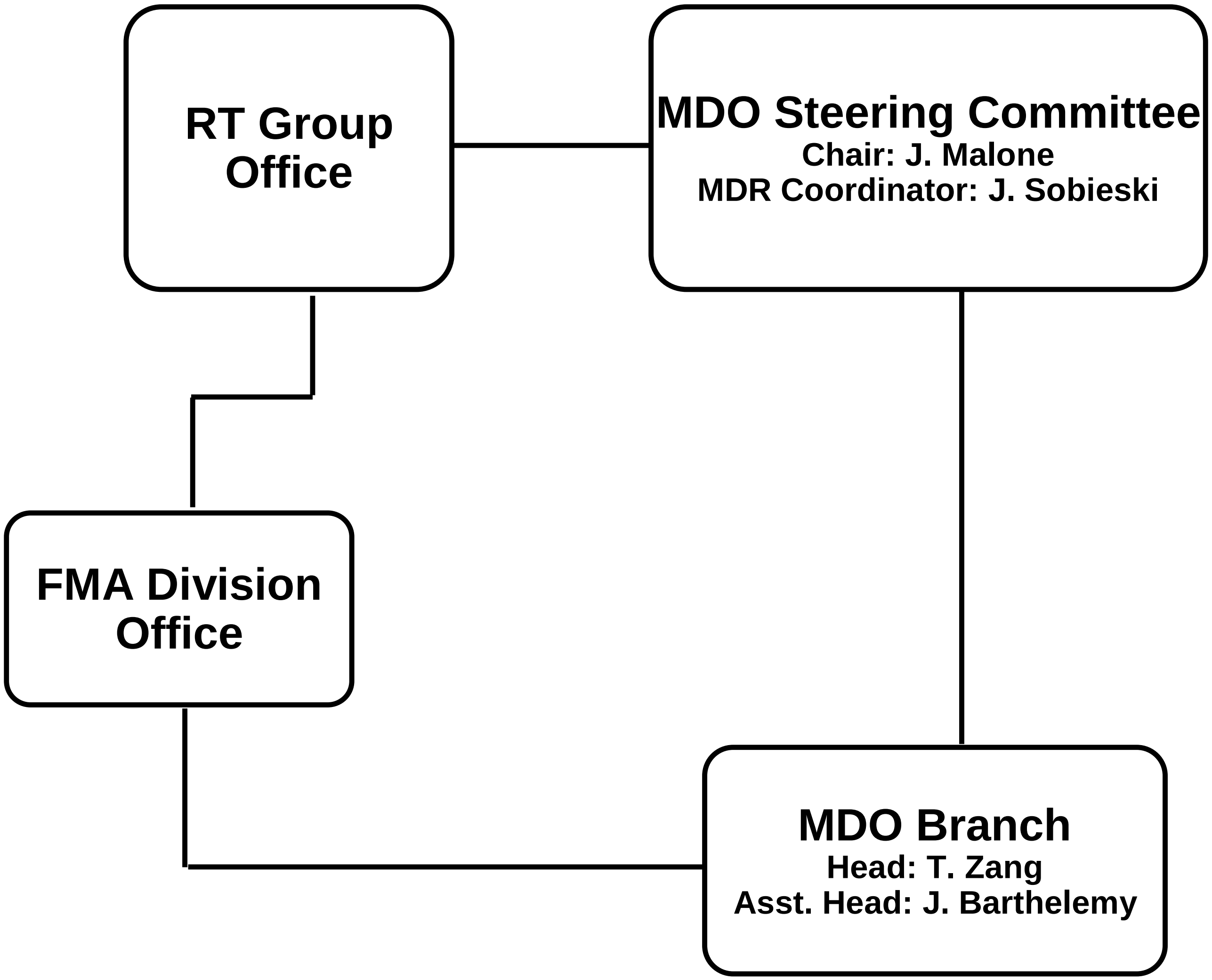
LaRC Organization 1994-1998



Research and Technology Group



MDO Organization in RTG



Significant MDO/ASCAC Events

1989	LaRC charters HiSAIR
1991	HPCCP MDO starts
1993	RTG & program offices established
1994	RTG charters LCAP Team
1994	MDO industry tour
1994	MDOB established
1995	MDOB rotorcraft industry tour
1995	AAC/ARTS review of NASA MDO "program"
1996	MDOB Peer Review
1997	RTG loses control of Base $
1998	ASCAC established
2000	*HPCCP ELVIS planning*
2001	ASCAC Methods Development Peer Review
2002	ASCAC strategic planning

1994 MDO Industry Tour

- **9 Half-Day visits in 6/94**
  - **Cessna & Learjet**
  - **McDonnell-Douglas, St. Louis**
  - **Northrop-Grumman (B-2 Division)**
  - **Lockheed-Martin, Palmdale**
  - **Boeing, New Large Airplane & Corporate R&D**
  - **Aerospace Corporation**
  - **McDonnell-Douglas, Huntington Beach**
- **Contemporaneous Contacts**
  - **Rockwell Chief Scientist at LaRC**
  - **HSR/LCAP efforts w. Boeing & McDonnell-Douglas**

Major Conclusions from 1994 MDO Industry Tour

- There is broad support for MDO research and applications
- New aerospace system design philosophy is to maximize affordability with constraints on performance
- Bringing cost into the design changes the fundamental mathematical nature of the design problem

1994 Industry Tour Summary: High Payoff MDO Development Areas

(*red italics* subjects are worked by MDOB)

- *CAD-based geometric modeling and parameterization*
- *Preliminary design capability including FEM-based structures, aerodynamics (loads)* **and acoustics (interior and exterior noise)**
- **P/A/S capability to simulate mission, identify critical dynamic loads and run through fatigue and damage assessment**
- **Virtual prototyping and virtual manufacturing**
- *MDO methodology to include* **discontinuous functions,** *discrete variables*, **statistical and** *probabilistic approaches*, **fuzzy logic, heuristics and knowledge bases**
- *Development of generic MDO tools [i.e., process management tools (DeMAID) and automatic differentiation tools (ADIFOR)]*
- *Help facilitate development of models for* **manufacturing and** *economics*

ASCoT Project (1998-2002)

(Aerospace Systems Concept to Test)

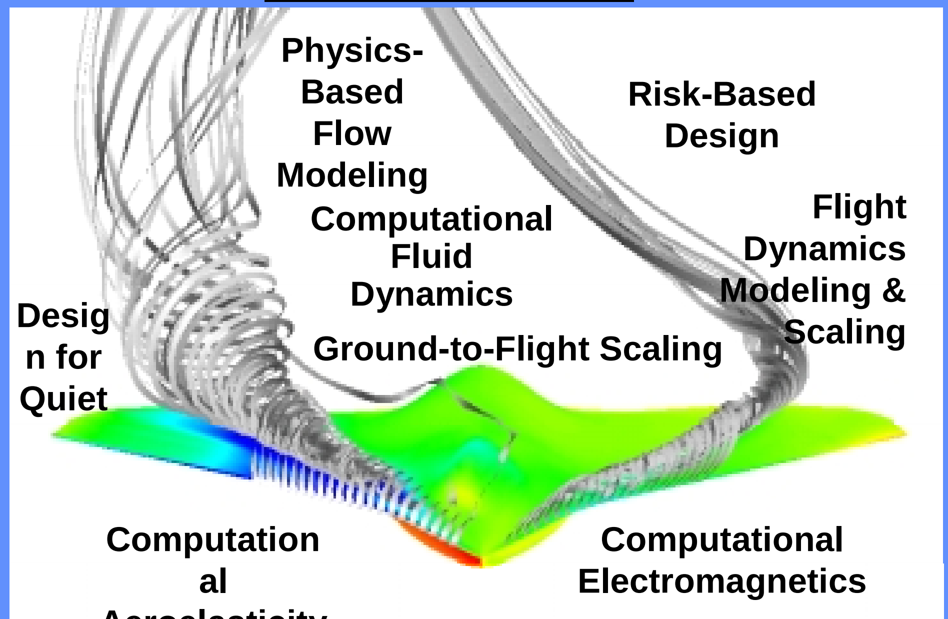
Project Vision

Physics-based modeling and simulation with sufficient speed and accuracy for validation and certification of advanced aerospace vehicle design in less than 1 year

Project Goal

- **Provide next-generation analysis & design tools to increase confidence and reduce development time in aerospace vehicle designs**

Technology Areas



Objective

- Develop **fast, accurate, and reliable** analysis and design tools via fundamental technological advances in:
  - Physics-Based Flow Modeling
  - Fast, Adaptive, Aerospace Tools (CFD)
  - Ground-to-Flight Scaling
  - Time-Dependent Methods
  - Design for Quiet
  - Risk-Based Design

Benefit

- Increased Design Confidence
- Reduced Development Time

Morphing Project (1998- 2002)

Long-Term Vision: *Aerospace Vehicles that Efficiently Adapt to Handle Diverse Mission Scenarios*

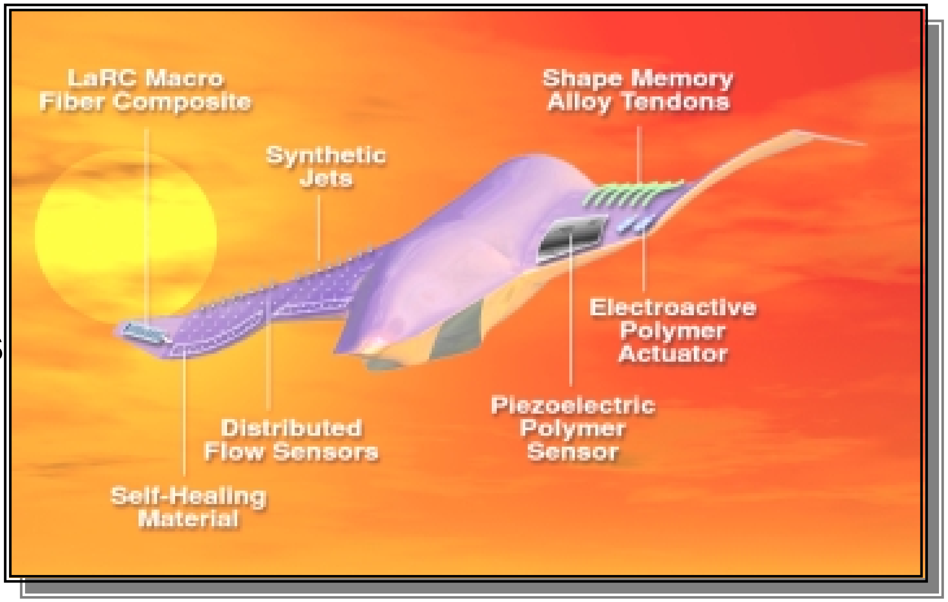
NASA Morphing Project Objective:

Develop and assess innovative, advanced technologies and integrated concepts to enal

Morphing

Technical Challenges:

- **Active materials for sensors and actuators**
- **Compliant, load-bearing structures**
- **Unsteady aerodynamics**
- **Non-intrusive, efficient electronics**
- **Optimization and Controls**
- **Manufacturability and Reliability**
- **New structural and vehicle control concepts**

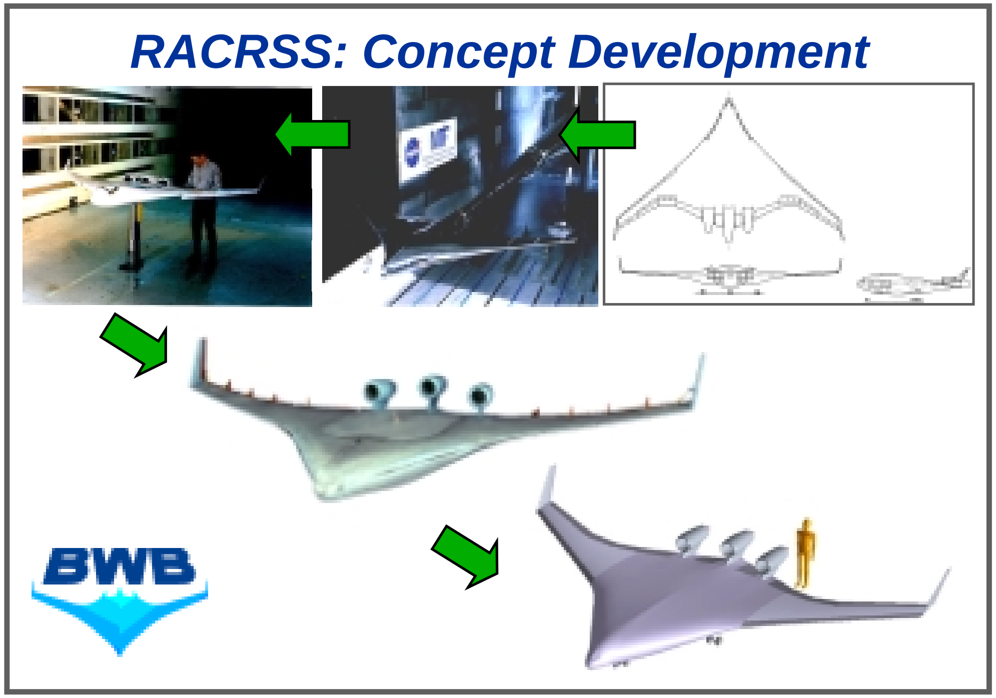


Technical Approach:

- **Create Innovative Technologies**
- **Address Application Issues**
- **Demonstrate Performance**
- **Devise Revolutionary Concepts**

RACRSS Project (2000-2001)
(Revolutionary Airframe Concept Research & System Studies)

Project Goal
- Accelerate the maturation of innovative aircraft concepts that have large potential impact on the Aeronautics Enterprise Three Pillars for Success Goals



Objectives
- Enhance interdisciplinary problem solving across base programs and with industry/academia
- Create, mature, and develop technology and configurations for application to experimental flight vehicles (X-Planes)

Benefit
- Significant acceleration in the development of viable advanced technologies and configurations
- Provide vehicle focus for integrated research within the Aeronautics Enterprise
- Identify potential experimental aircraft (X-Plane) concepts

Ultra-Efficient Engine Technology

Propulsion Airframe Integration Project (2000-2002)

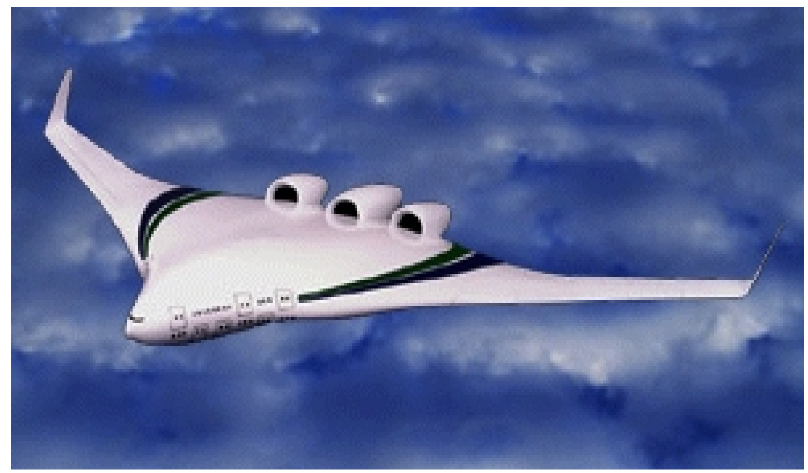
Goal: Reduce aircraft CO_2 emissions by developing advanced technologies to yield lower drag propulsion system integration for a wide range of vehicle classes

Conventional Configuration

Enable Ultra High Bypass Ratio Engine Integration

- Advanced CFD design methods
- Active Shape Control Variable Area Nozzle
- Active Shape Control Variable Radius Nacelle Leading Edge

Revolutionary Configuration



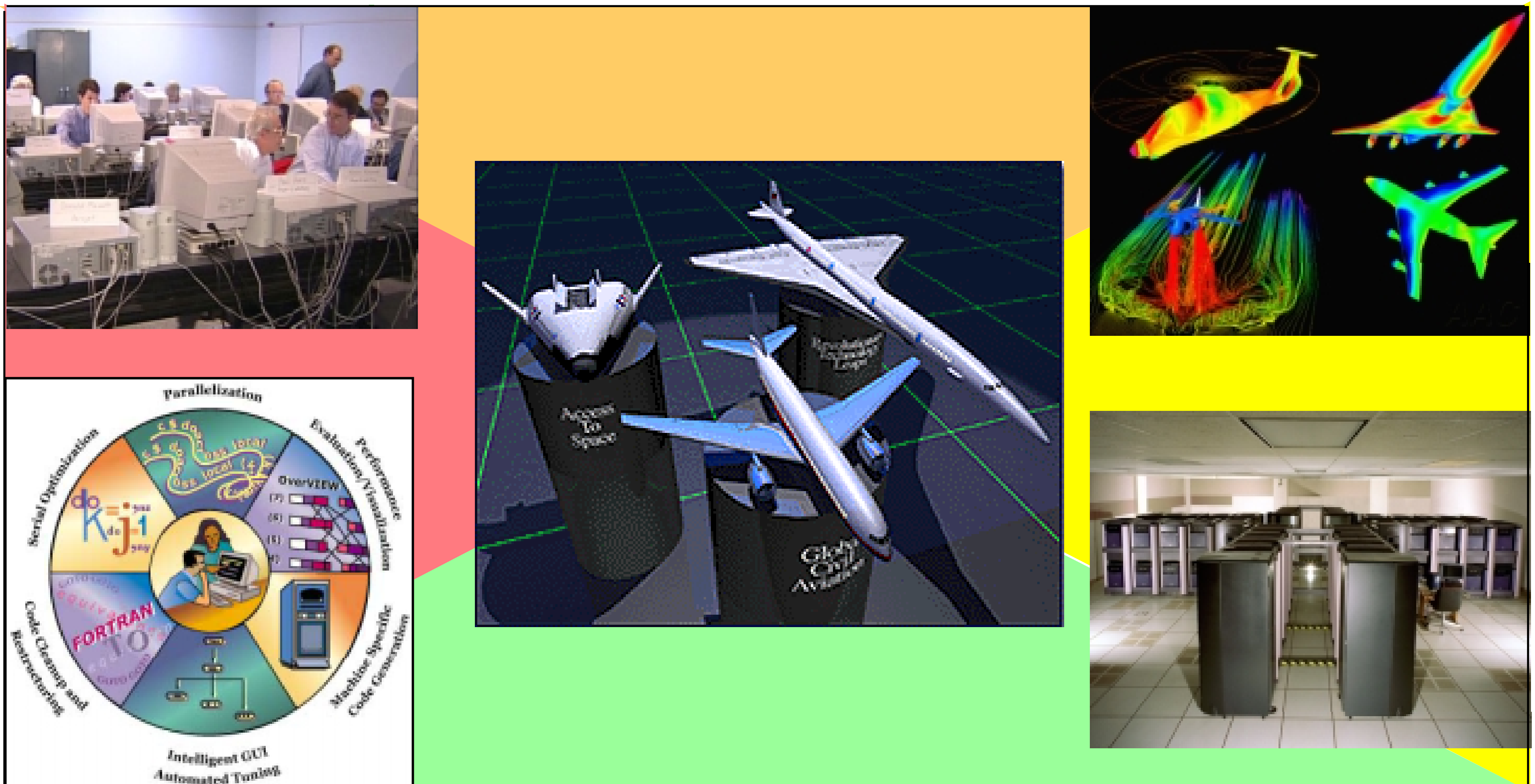
Enable Boundary Layer Ingestion S-inlet Nacelle Integration

- Advanced CFD design methods
- Active Flow Control S-inlets
- Active Flow Control boundary layer reenergization

HPCC Program (1992-2001)

(High Performance Computing and Communications)

- **Computational AeroSciences Goal**
  - **Enable improvements to NASA technologies and capabilities in aerospace transportation through the development and application of high-performance computing technologies and the infusion of these technologies into the NASA and national aerospace**



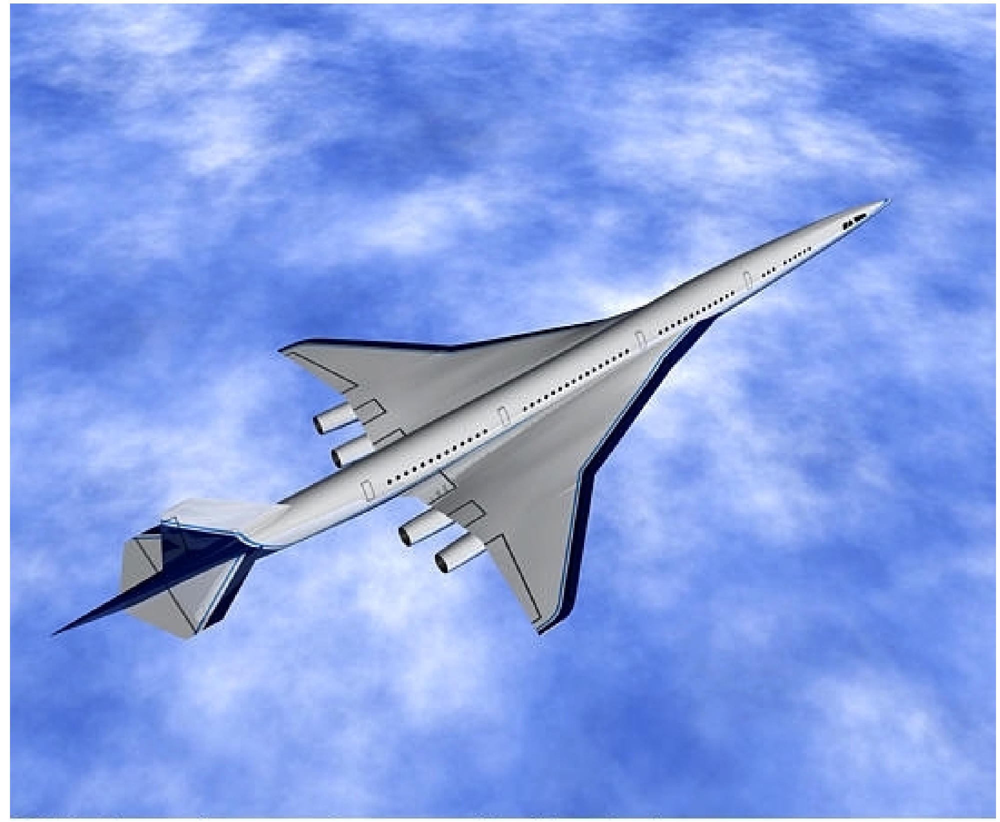
HSR Program (1990-1999)
(High Speed Research)

Phase I (1990-92) Goal:

develop technology concepts for environmental compatibility

Phase II (1993-99) Goal:

demonstrate the environmental technologies and define and demonstrate selected high-risk technologies for economic viability



ISE Program (2000-2001)

(Intelligent Synthesis Environment)

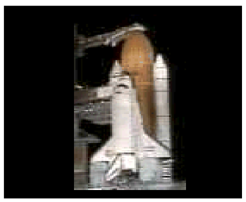
<u>Vision</u>

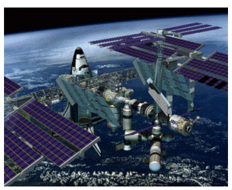
To effect a cultural change that integrates into practice widely-distributed science, technology and engineering teams to rapidly create innovative, affordable products

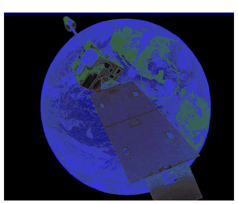
<u>Long-Term Goal</u>

To develop the capability for personnel at dispersed geographic locations to work together in a virtual environment, using computer simulations to model the complete life-cycle of a product/mission with near real-time response time before commitments are made to produce physical products

ISE Large-Scale Applications
(NASA is the Customer)







- **Reusable Space Transportation Systems (RSTS)**
  - **Develop and demonstrate an integrated environment (w/distributed users, applications and data) to support RSTS design from concept analysis through detailed system design, including mission performance, risk, and life-cycle costs [now called AEE]**
- **Shuttle**
  - **Ability to support/perform virtual Shuttle assessments (e.g. technical, operational, programmatic), and incorporation of external data for system visualization**
- **International Space Station**
  - **Create a virtual International Space Station "simulator" that will model the ISS vehicle and system performance in any user-selected configuration and environment**
- **Integrated Exploration and Science**
  - **Life-cycle simulation of missions to Mars in a realistic Martian environment for the purpose of mission and system design, project science planning, and mission operations**
- **Advanced Earth Observation**
  - **Mission simulation and simulation-aided-design of science missions, both Earth and Space Science, starting with the definition of science measurement and phenomena, and ending with a visualized, simulated validation of the systems design to take the measurement**

2nd Generation RLV Project
(2001-2002)

- **NASA's goals for the second generation RLV are to:**
  - **Improve the expected safety of launch so that by the year 2010 the probability of losing a crew is no worse than 1 in 10,000 missions.**
  - **Reduce the cost of delivering a pound of payload to low Earth orbit from today's $10,000 down to $1000 by the year 2010.**
- **2nd Gen RLV/AEE Objective**
  - **Deliver to the 2nd Generation RLV Program and ISAT Team “an advanced engineering synthesis environment complete with life-cycle simulation models capable of modeling technology, uncertainty, co**